Financial Impact of Surgical Care for Scoliosis, Developmental Hip Dysplasia, and Slipped Capital Femoral Epiphysis in Children

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Abstract: National estimates of pediatric musculoskeletal (MSK) conditions, their prevalence and costs, as well as the impact of surgery, are virtually nonexistent. In this paper, we provide national estimates of surgery frequency and hospital costs of scoliosis, developmental hip dysplasia (DDH), and slipped capital femoral epiphysis (SCFE). In this paper we utilize 3 established data bases and the U.S. Census Bureau to estimate utilization, hospital costs, and separate inpatient and outpatient procedural volume. In 2012, U.S. annual surgical procedure estimates were 9,607 for scoliosis, 2,554 for DDH, and 2,464 for SCFE. Inpatient surgery was more common for each of these conditions, with 94% of scoliosis, 73% of DDH, and 62% of SCFE surgeries performed in the inpatient hospital setting. Total annual hospital costs for the three surgeries were almost $400 million (2012 USD), with scoliosis surgery accounting for 91% of these costs. Surgery has the potential to reduce the societal burden of these conditions. More research is needed to appreciate what the financial burden would have been for the natural history of these conditions.

Key Concepts:

- National estimates of the prevalence and costs of pediatric musculoskeletal conditions and the impact of surgery are virtually nonexistent, particularly for non-trauma related conditions**.**
- In 2012, U.S. annual surgical procedure estimates were 9,607 for scoliosis, 2,554 for DDH, and 2,464 for SCFE.
- Hospital costs related to surgery for scoliosis, DDH, and SCFE are significant but likely represent only a fraction of the full societal costs of these conditions.
- There are challenges with obtaining data on pediatric musculoskeletal conditions and measuring their long-term financial impact on patients and society.

Introduction

Musculoskeletal (MSK) conditions represent a significant burden of disease in the United States. In terms of leading causes of years lived with disability in the U.S., back/neck conditions and other musculoskeletal conditions were ranked first and fifth, respectively.[1] The burden of MSK conditions also results from significant direct costs incurred by society as individuals seek care for their conditions. These direct costs include $55 billion in inpatient hospital costs from 3.3 million MSK inpatient discharges in 2014.[2] Another contributor to the burden of MSK conditions is lost productivity from MSK conditions. One estimate put these indirect costs for adults with a work history at $77.5 billion in 2011.[3]

Since 2005, there has been increasing recognition of the potential value of surgery on reducing the international burden of MSK diseases.[4] However, estimates of the burden of surgically treated conditions, MSK or other, and the ability of surgery to reduce that burden are limited. In the U.S., several studies have examined the cost-effectiveness of surgical treatment for specific MSK conditions in adults, after fully accounting for the potential impacts of surgery on patients' lifetime productivity. After accounting for indirect cost savings from greater productivity, these studies have demonstrated net societal savings from the surgical treatment of MSK conditions, such as hip and knee replacement.[5-6]

Relative to adults, estimates of the prevalence and burden of pediatric MSK conditions and the impact of surgery are largely unavailable in the U.S., particularly for non-trauma related conditions. Conceptually, pediatric MSK conditions may impose a greater societal and economic burden than adult-onset MSK conditions because they can impact an individual over a longer time period. Indirect costs from life-long diseases may be more significant for conditions that appear in childhood. For many pediatric MSK conditions, however, there is a critical gap in our knowledge about the burden and the role of surgery. The purpose of this study is to produce national estimates of the prevalence and hospital costs for selected pediatric MSK conditions as well as to identify gaps in our understanding of their financial impact and areas for future research.

In this study, we focus on scoliosis, developmental hip dysplasia (DDH), and slipped capital femoral epiphysis (SCFE). We choose to study these three conditions because they have the potential to significantly impact long-term costs and are commonly and effectively treated with surgery. We provide national estimates of the prevalence and hospital costs of surgical treatment for these conditions in inpatient and outpatient settings. In addition, we conduct a literature review on the effects of surgery for these conditions, with a focus on long-term economic outcomes.

Materials and Methods

Selection of Conditions. We convened an advisory panel of six pediatric orthopedic surgeons ("Advisory Panel") from six institutions to identify which pediatric MSK diseases to study and performed a literature review and prevalence estimates for each selected condition. The three conditions that were agreed upon through a consensus approach were: scoliosis, DDH, and SCFE. The Advisory Panel reviewed *The Ninth Edition International Classification of Diseases (ICD-9)* diagnosis and procedure codes and considerations for age restrictions for each condition (See Appendix A for ICD-9 codes). The Advisory Panel specified appropriate age ranges for each condition (scoliosis patients 0 to 25 years old, DDH patients 0 to 10 years old, and SCFE patients 6 to 16 years old) based on clinical experience. To assess the burden of the selected conditions, we analyzed data to generate prevalence rates and direct costs. We conducted a literature review to determine the indirect effects associated with each condition.

Data and Data Analysis. We analyzed three data sources: (1) 2012 Kids' Inpatient Database (KIDs); (2) 2011 State Ambulatory Surgery and Services Database (SASD) for California (CA), and 2012 SASD for six states (Colorado, Florida, Kentucky, Maryland, New Jersey, and New York); and (3) 2006-2011 National Ambulatory Medicare Care Survey (NAMCS). KIDs is a pediatric inpatient database that reports data on procedures, charges, and ages. Inpatient surgery estimates were derived from this database. We used the selected SASD data to quantify the number of outpatient surgeries for the selected conditions. We then created an outpatient surgery utilization rate (number of surgeries across all selected states divided by the total population in all selected states) for each age and gender using the SASD and population estimates from the U.S. Census. These utilization rates were converted into national estimates of the number of surgeries by multiplying by national population counts by age and gender. NAMCS and the U.S. Census data from 2006-2011 were used to report physician visit rates per 10,000 children for each condition. Direct cost estimates were calculated by applying hospital-wide cost-to-charge ratios (CCRs) to surgical charges, as reported in KIDs and SASD. For each state, the CCR was derived from KIDs and the Center for Medicare & Medicaid Services' impact files. Note, CA SASD did not include any charge information and was excluded from our cost estimates.

Literature Review. A literature review was performed by two reviewers using the PubMed (National Center for Biotechnology Information, National Institutes of Health, Bethesda, MD) database for the following search terms: scoliosis, hip dislocation, congenital, and slipped capital femoral epiphyses (See Appendix B for the complete list of search terms and search strategy). Studies were excluded if they focused on other conditions or if their patient population did not observe adolescents and young adults at the time of treatment. To ensure a comprehensive search, references within identified studies were further searched to include relevant articles missed in the initial search. A reconciliation process was used with a third researcher when disagreements about study inclusion occurred. The Advisory Panel was involved in the literature review process and provided subject matter expertise on matters regarding the selected pediatric MSK conditions. After reviewing the titles, abstracts, and full text, we included 11 articles in this study (See Appendix C for the literature review attrition chart). We report on three studies in this report.

Results

Prevalence

Scoliosis. In 2012, approximately 9,607 total scoliosis surgeries were performed in inpatient and outpatient settings. Nearly all surgeries (94%) were performed in an inpatient setting (Table 1). In both settings, female patients accounted for more than twice as many surgeries as males (Table 2). Children between the ages of 11 and 16 years old accounted for 78% of all scoliosis inpatient surgeries. However, children between the ages of 0 and 5 accounted for the majority (66%) of scoliosis surgeries performed in the outpatient setting. There was no correlation between age and rate of surgery across settings.

Between 2006 and 2011, a total of 2,924,521 pediatric visits occurred within physicians' offices with scoliosis as the primary reason for the visit. On average, physicians' offices were host to 487,420 scoliosis cases each year. We analyzed physician visits during 2 three-year periods (2006-2008 vs. 2009-2011) and observed an increase of 23 visits per 10,000 individuals among scoliosis patients over the time periods (33 vs. 56; See Appendix D). Across the entire time period, we estimated an average of 45 physician visits for scoliosis per 10,000 individuals.

DDH. In 2012, approximately 2,554 DDH surgeries were performed in inpatient and outpatient settings. Like scoliosis, most surgeries (73%) were performed in the inpatient setting (Table 1). There were more female DDH patients receiving surgery in both settings (Table 2). Among children receiving DDH surgery in the inpatient setting, 63% were between the age of 0 and 5. Children that received DDH survey in the outpatient setting tended to be younger than those receiving surgery in the inpatient setting with approximately 96% of outpatient surgeries being performed on patients between the age of 0 and 5.

Between 2006 and 2011, a total of 356,289 pediatric visits occurred in physicians' offices with DDH as the primary reason for the visit. On average, physicians' offices were host to 57,717 DDH patient visits each year. For the treatment of DDH, we estimated an increase of six visits per 10,000 individuals between 2006-2008 and 2009-2011 (10 vs. 16). Over the 6-year span, we estimated that an average of 13 per 10,000 individuals visited a medical professional for DDH (Table A1).

SCFE. We estimated that a total of 2,464 SCFE surgeries were performed in inpatient and outpatient settings. Compared to the other conditions, SCFE had the highest percentage of surgeries performed in an

Table 1. Total Procedures by Age and Health Setting

	Scoliosis			DDH			SCFE		
Age Range	**Total Count**	**Inpatient Setting (%)**	**Outpatient Setting (%)**	**Total Count**	**Inpatient Setting (%)**	**Outpatient Setting (%)**	**Total Count**	**Inpatient Setting (%)**	**Outpatient Setting (%)**
0-5 years	442	18%	82%	1,837	64%	36%	-	-	-
6-10 years	613	79%	22%	718	96%	4%	435	62%	38%
11-16 years	7,139	99%	1%	-	-	-	2,029	62%	38%
17-20 years	1,414	100%	0%	-	-	-	-	-	-
Total	9,607	94%	6%	2,554	73%	27%	2,464	62%	38%

Note: Observations less than 11 are blinded in order to be compliant with HCUP's Data Use Agreement
Sources: Analysis of 2012 National Kids' Inpatient Database; 2011 CA, 2012 CO, KY, MD, NJ, and NY State Ambulatory Surgery and Services Databases; and 2010-2015 U.S. Census Data. KID data only reports patients up to 20 years of age.

Table 2. Estimates of National Inpatient and Outpatient Procedures by Diagnosis, Age, and Gender

	Inpatient								
	Scoliosis			**DDH**			**SCFE**		
Age Range	**Female**	**Male**	**Total**	**Female**	**Male**	**Total**	**Female**	**Male**	**Total**
0-5 years	49	29	78	825	349	1,175	-	-	-
6-10 years	367	114	482	365	327	692	196	75	271
11-16 years	5,339	1,748	7,087	-	-	-	443	808	1,250
17-20 years	854	560	1,414	-	-	-	-	-	-
Total	6,610	2,450	9,061	1,190	676	1,866	639	882	1,521

	Outpatient								
	Scoliosis			**DDH**			**SCFE**		
Age Range	**Female**	**Male**	**Total**	**Female**	**Male**	**Total**	**Female**	**Male**	**Total**
0-5 years	258	105	363	574	88	662	-	-	-
6-10 years	90	42	132	10	16	26	113	52	164
11-16 years	32	19	51	-	-	-	228	550	778
17-20 years	-	-	-	-	-	-	-	-	-
Total	381	166	546	583	105	688	341	602	943

Note: Observations less than 11 are blinded in order to be compliant with HCUP's Data Use Agreement
Sources: Analysis of 2012 National Kids' Inpatient Database; 2011 CA, 2012 CO, KY, MD, NJ, and NY State Ambulatory Surgery and Services Databases; and 2010-2015 U.S. Census Data. KID data only reports patients up to 20 years of age.

Table 3. Total Costs by Age and Health Setting

	Scoliosis			DDH			SCFE		
Age Range	**Total Cost**	**Inpatient Setting (%)**	**Outpatient Setting (%)**	**Total Cost**	**Inpatient Setting (%)**	**Outpatient Setting (%)**	**Total Cost**	**Inpatient Setting (%)**	**Outpatient Setting (%)**
0-5 years	$3,247,150	92%	8%	$12,284,815	95%	5%	-	-	-
6-10 years	$20,383,115	99%	1%	$9,071,627	100%	0%	$1,775,306	93%	7%
11-16 years	$281,644,741	100%	0%	-	-	-	$8,479,136	94%	6%
17-20 years	$57,951,178	100%	0%	-	-	-	-	-	-
Total	$363,226,184	100%	0%	$21,356,443	97%	3%	$10,254,443	94%	6%

Note: Observations less than 11 are blinded in order to be compliant with HCUP's Data Use Agreement
Sources: Analysis of 2012 National Kids' Inpatient Database; 2012 CO, KY, MD, NJ, and NY State Ambulatory Surgery and Services Databases; and 2010-2015 U.S. Census Data. KID data only reports patients up to 20 years of age.

Table 4. Estimates of Average Inpatient and Outpatient Costs by Diagnosis and Age

	Inpatient			Outpatient		
Age Range	**Scoliosis**	**DDH**	**SCFE**	**Scoliosis**	**DDH**	**SCFE**
0-5 years	$38,236	$9,978	-	$742	$849	-
6-10 years	$41,924	$13,094	$6,064	$1,415	$25	$804
11-16 years	$39,731	-	$6,396	$1,482	-	$618
17-20 years	$40,976	-	-	-	-	-
All Ages	$40,029	$11,133	$6,337	$974	$841	$651

Note: Observations less than 11 are blinded in order to be compliant with HCUP's Data Use Agreement
Sources: Analysis of 2012 National Kids' Inpatient Database; 2012 CO, KY, MD, NJ, and NY State Ambulatory Surgery and Services Databases; and 2010-2015 U.S. Census Data. KID data only reports patients up to 20 years of age.

Table 5. Estimates of Average Inpatient and Outpatient Costs by Diagnosis and Age and Gender

	Inpatient						Outpatient					
	Scoliosis		DDH		SCFE		Scoliosis		DDH		SCFE	
Age Range	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
0-5 years	$32,888	$41,774	$10,103	$10,226	$0	$0	$839	$774	$980	$1,156	$0	$0
6-10 years	$41,587	$41,211	$13,172	$13,023	$5,816	$5,661	$1,367	$1,549	$812	$538	$774	$919
11-16 years	$38,546	$44,382	$0	$0	$7,941	$6,710	$1,517	$1,623	$0	$0	$671	$778
17-20 years	$38,238	$45,126	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total	$38,444	$44,303	$10,786	$11,744	$6,484	$6,231	$983	$953	$826	$930	$619	$668

outpatient setting (38%) (Table 1). Most patients received surgery between the ages of 11 and 16. In both settings, male patients were more likely to receive surgery compared to female patients (Table 2). However, for children between the ages of 6 and 10, surgery was more prevalent among males for children while surgery was more prevalent among males for children between the ages of 11 and 16.

No SCFE cases were recorded in the NACMS data during 2006-2011. Consequently, we were not able to estimate the count and rate of physician visits by SCFE patients.

Costs

Scoliosis. Based on our analysis of KIDs and SASD data, we calculated the total hospital cost of scoliosis surgery in inpatient and outpatient settings. Overall, estimated scoliosis surgery costs equaled $363 million. Among the three conditions, the total estimated costs across settings were highest for patients receiving scoliosis surgery. Inpatient costs accounted for almost all costs (100%) (Table 3).

In addition to total hospital costs, we also estimated the average cost of scoliosis surgery. For patients aged 20 years or younger, the average national inpatient cost of pediatric scoliosis was $40,029 (Table 4). Across all ages, costs were typically higher among male patients ($44,303 v. $38,444). The average cost for outpatient scoliosis surgery was $974.

DDH. In total, DDH surgery costs equaled an estimated $21 million across both inpatient and outpatient settings. Like scoliosis costs, nearly all DDH surgery costs came from inpatient procedures (97%). We calculated average inpatient and outpatient hospital costs for patients 10 years and younger admitted for DDH surgery. The average cost of inpatient DDH hip surgery was $11,133. Surgery for male patients was, on average, costlier than for their female counterparts ($11,744 vs. $10,786). Outpatient DDH surgery costs were $841 on average. Outpatient costs per procedure were typically higher for males and patients below the age of four.

SCFE. Total estimated hospital costs associated with SCFE hip surgery were $10 million. Compared to the three other conditions, total outpatient costs were highest for SCFE patients. However, outpatient SCFE costs only accounted for 6% of total SCFE surgical costs. We estimated the average cost of SCFE hip surgery for patients between the ages of 6 and 16 years old. On average, SCFE hip surgery costs $6,337 in the inpatient setting. Although cost differences are not associated with age, female patients were, on average, slightly more costly than male patients ($6,484 vs. $6,231) (Table 5). The average cost of SCFE in the outpatient was $651.

Long-Term Economic Effects

We conducted a literature review to identify the long-term economic consequences of scoliosis, DDH, and SCFE. Some studies examined work status and absenteeism among adults who were treated for scoliosis. Other studies examined the psychological and psychosocial effects of scoliosis. Such factors, while reflecting well-being, may also be correlated with economic outcomes. We were unable to identify any studies that assessed how treated or untreated DDH and SCFE can affect work status, and we only included studies that examined work status and absenteeism among adults treated for scoliosis.

Work Status and Sick Leave

Work status can strongly influence the economic burden and have a negative effect on individual well-being. Long-term follow-up studies (10-20 years) indicate high rates of employment among adolescent idiopathic scoliosis (AIS) patients after surgical treatment.[7-8] In three studies, 58-85% of AIS patients were employed at the time of follow-up.[7-9]

The only study with a control group was reported by Danielsson et al. (2001), which examined patients who were treated with distraction and fusion using Harrington rods or with a brace.[7] AIS patients who received surgical treatment alone were found to have lower employment rates (75%, n=109), but among those with current employment, a higher percentage of patients were working full time (34%, n=73) when compared to the healthy control group. In the control group, 81% of individuals were employed (n=81), with 30% working full-time (n=80). Most AIS patients working full-time have jobs requiring relatively heavy work or light work with some physical activity. Compared to the AIS patients, the control group was more likely to have jobs requiring light work with some physical activity. The treatment group had more individuals listed as sick or retired (n=4), with the back listed as the primary or in combination reason for 11 patients. However, AIS patients were also more likely to take sick leave due to back problems compared to their healthier counterparts (43% vs. 10%).

The other two studies were noncontrolled intervention studies.[8-9] Both studies examined AIS patients who had undergone spinal correction surgery, but Bjerkreim et al. (2007) examined Norwegian patients, of whom 32% had brace treatment before surgery while Spanyer et al. (2015) had 37% (n=31) of patients who were braced before surgery. Spanyer et al. followed up with patients 7 to 17 years after surgical treatment. At follow-up, 85% (n=100) of AIS patients were employed, with 77% (n=91) working at a desk job. Bjerkreim et al. reported the lowest rate of employment with only 58% of surgery patients working (full-time or part-time) at 10-year follow-up, and 20% on sick leave, rehabilitation, or disability pension. AIS patients were also asked job and education-related questions due to their condition. Sixteen percent of patients indicated that back pain or disability was a reason for changing jobs, and 37% indicated that their choice of education and job was influenced by scoliosis.

Discussion

In this paper, we provide national estimates of surgery frequency and hospital costs and conduct an assessment of the potential long-term economic consequences of scoliosis, DDH, and SCFE. These conditions have the potential to impact long-term costs significantly and are effectively treated with surgery.

Our quantitative analysis to estimate healthcare utilization has several limitations. First, we relied on six state databases to estimate the number of outpatient surgeries for the selected conditions. We extrapolated to the national level from these state databases, but the included states may not be an accurate representation of outpatient surgeries in other states. In addition, not all states included surgeries in free-standing ambulatory surgical centers. Although we expect few pediatric surgeries in these facilities, our estimates may undercount outpatient surgeries because of this omission. Because of limitations in our available data, our analyses focused on hospital costs and did not capture the full cost of caring for the three conditions across care settings. Finally, we used hospital-wide cost-to-charge ratios to convert inpatient and outpatient charges to costs.

Despite the above concerns, we estimate that a total of 14,625 surgeries were performed across the three selected conditions in 2012, with surgery for scoliosis accounting for 66% or 9,607 of these surgeries. Our national estimates suggest a surgery rate of 11, 6, and 5 per 100,000 adolescents for scoliosis, DDH, and SCFE, respectively. While most surgeries were performed as inpatients, we estimate that 27 and 38 percent of DDH and SCFE surgeries were performed in the hospital outpatient setting. For scoliosis, children aged 0 to 5 years old were likely to receive surgery in an outpatient setting, while older children were overwhelmingly more likely to receive surgery in the inpatient hospital setting. For children aged 0 to 5 years old, DDH surgery was performed in the outpatient setting in 36% of cases, while those between the age of 6 and 10 received DDH surgery in the outpatient setting in only 6% of cases.

We estimate that hospitals incurred close to $400 million of surgical costs to treat scoliosis, DDH, and SCFE, with scoliosis surgery representing 91% of costs. Outpatient costs account for less than 1% of the total hospital costs associated with the three selected conditions. The average per procedure hospital costs for inpatient surgeries were significantly higher than outpatient surgeries and ranged from $40,029, $11,133, and $6,337 for inpatient scoliosis, DDH, and SCFE surgery, respectively. By comparison, there were a total of 2,505 non-neonatal inpatient hospital stays per 100,000 children aged 0 to 17 in 2012 at an average cost of $11,143 per stay.[11] Our results confirm the relatively high cost of scoliosis inpatient surgery, while surgery for DDH is about equal to the average, and SCFE is a little more than half the average costs of inpatient surgery for children.

Unfortunately, we found little research on the long-term economic consequences of the conditions studied. Such a result likely reflects the challenge of tracking lifetime costs for untreated patients as well as the surgical outcomes for children over their lifetime. Our literature review suggests that individuals with AIS who receive corrective surgery have high employment rates post-surgery[7-9] but may have lower work productivity as a result of missed work due to back issues.[7] While we found no studies on the impact of DDH or SCFE in children on future work status, DDH is associated with early onset of osteoarthritis[12], which is linked to reduced productivity at work.[13]

The potential role of surgery in reducing the burden of scoliosis, DDH, and SCFE is complex. Early interventions could produce quality of life benefits that may accrue over a patient's lifetime and reduce the burden of disease. The primary concern of physicians when treating scoliosis in adolescents is to prevent the progression of spine curvature which can lead to decreased quality of life. Several studies have demonstrative that spinal correction can improve quality of life.[7-8,10] Danielsson et al. demonstrated that patients treated for AIS can have equivalent health-related quality of life scores compared to the general population.[7]

Since the 1950s, researchers have noted that the late or delayed treatment of DDH can lead to serious disabilities and morbidities.[14-17] In their 2005 study, Angliss et al. found that 40% of patients who received late surgical treatment of DDH suffered from moderate to severe osteoarthritis more than 30 years after surgery.[18] The appearance of DDH in children has been shown to be at least marginally predictive of developing hip osteoarthritis later in life.[19] In fact, several studies have posited that "idiopathic" osteoarthritis may be a result of untreated hip dysplasia.[20-22] Consequently, the surgical treatment of DDH may help reduce long-term morbidity and disability, and significantly improve the afflicted individuals' quality of life.

Evidence from childhood chronic condition suggests that poorly managed medical conditions, like asthma[23] and juvenile idiopathic arthritis,[24] results in missed school for children, and lower work productivity for parents. Similar impacts may be possible from delayed treatment or inappropriate management of MSK conditions in children.

From a long-term economic standpoint, the effects of surgery depend on how surgical treatment affects a child's educational choices and other complex decisions. Prior studies have estimated significant indirect cost savings from greater productivity as a result of adult surgery for ACL tears and hip osteoarthritis.[5-6] If surgery for scoliosis, DDH, and SCFE similarly reduces pain and improves function, then surgical treatment from these conditions may offer significant societal benefits over an individual's lifetime. Our literature review suggests the potential for long-term economic benefits of surgery for the studied conditions. However, we did not find any literature that directly addressed these long-term economic questions.

The findings highlight several gaps in the topic areas of economic research on these selected MSK conditions. First, we found a few studies that sought to estimate the economic impact of these selected MSK conditions, but none on long-term impacts. The studies that we did find focused on work status and absenteeism on individuals with scoliosis, but none on how that might translate into financial estimates. Also, no studies were identified that sought to estimate the medical and indirect costs of these conditions. Third, we did not identify any studies that focused on younger pediatric patients for these selected conditions. The studies that we did identify focused on adolescents.

Conclusions

This study is one of the first to provide national estimates of the number and hospital costs associated with surgery for scoliosis, DDH, and SCFE. Such information is needed to understand the burden associated with these conditions and to support health systems' move into risk-sharing models. Our study highlights the existing gap in evidence on both the short-term and long-term costs, and both medical and indirect costs, associated with scoliosis, DDH, and SCFE. Like non-pediatric conditions, achieving a better understanding of these costs is an area for future research.

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Appendix A. Ninth Edition International Classification of Diseases Diagnosis and Condition Codes

ICD-9 Diagnosis Codes

Scoliosis Diagnosis ICD-9 Codes	
73730-73734 & 73739	Kyphoscoliosis and scoliosis
73743	Scoliosis associated with other conditions

Slipped Capital Femoral Epiphysis Diagnosis ICD-9 Codes	
7322	Nontraumatic slipped upper femoral epiphysis

Developmental Dysplasia of the Hip Diagnosis ICD-9 Codes	
75430-75433 &75435	Congenital dislocation of hip
75561-75563	Congenital deformity of hip (joint)

ICD-9 Procedure Codes

Scoliosis Procedure ICD-9 Codes	
8100-8109	Spinal fusions, multiple techniques
8130-8139	Refusion of the spine, multiple techniques
8161-8164	Other procedures of the spine
8451	Insertion of interbody spinal fusion device

Slipped Capital Femoral Epiphysis Procedure ICD-9 Codes	
7885	Internal fixation of bone without fracture reduction, femur
7945	Closed reduction of separated epiphysis, femur
7955	Open reduction of separated epiphysis, femur
7965	Debridement of open fracture site, femur
7975	Closed reduction of dislocation of hip
7985	Open reduction of dislocation of hip
7995	Unspecified operation on bone injury, femur

Developmental Dysplasia of the Hip Procedure ICD-9 Codes	
7725	Femoral wedge osteotomy (Wedge osteotomy, femur)
7735	Femoral division not elsewhere classified (NEC) (Other division of bone, femur)
7739	Bone division NEC (Other division of bone, other bones)
7825	Limb short proc-femur (Limb shortening procedures, femur)
7885	Internal fixation of bone without fracture reduction, femur
7945	Closed reduction of separated epiphysis, femur
7955	Open reduction of separated epiphysis, Femur
7975	Closed reduction of dislocation of hip
7985	Open reduction of dislocation of hip
7995	Unspecified operation on bone injury, femur
8140	Repair of hip, NEC (Repair of hip, not elsewhere classified)
8312	Adductor tenotomy of hip

Current Procedural Terminology (CPT) Codes

Scoliosis CPT Codes	
20680	Removal of implant; deep (e.g. buried, wire, pin, screw, metal band, nail, rod or plate)
29010	Application of Risser jacket, localizer, body; only
29888	Arthroscopically aided anterior cruciate ligament
20931	Allograft for spine surgery only; structural
20936	Autograft for spine surgery only (includes harvesting the graft); local (e.g., ribs, spinous process, or laminar fragments) obtained from same incision
20937	Autograft for spine surgery only (includes harvesting the graft); morselized (through separate skin or fascial incision)
20938	Autograft for spine surgery only (includes harvesting the graft); structural, bicortical or tricortical (through separate skin or fascial incision)
22206	Osteotomy of spine, posterior or posterolateral approach, three columns, one vertebral segment (e.g., pedicle/vertebral body subtraction); thoracic
22207	Osteotomy of spine, posterior or posterolateral approach, three columns, one vertebral segment (e.g., pedicle/vertebral body subtraction); lumbar

22208	Osteotomy of spine, posterior or posterolateral approach, three columns, one vertebral segment (e.g., pedicle/vertebral body subtraction); each additional vertebral segment
22212	Osteotomy of spine, posterior or posterolateral approach, one vertebral segment; thoracic
22214	Osteotomy of spine, posterior or posterolateral approach, one vertebral segment; lumbar
22216	Osteotomy of spine, posterior or posterolateral approach, one vertebral segment; each additional vertebral segment
22250	Removal of posterior nonsegmental instrumentation (e.g., Harrington rod)
22800	Arthrodesis, posterior, for spinal deformity, with or without cast; up to 6 vertebral segments (levels)
22802	Arthrodesis, same; 7 to 12 vertebral segments (levels)
22804	Arthrodesis, same; 13 or more vertebral segments (levels)
22806	Arthrodesis, anterior, for spinal deformity, with or without cast; 2 to 3 vertebral segments (levels)
22808	Arthrodesis, anterior, same; 4 to 7 vertebral segments (levels)
22812	Arthrodesis, anterior, same; 8 or more vertebral segments (levels)
22840	Posterior nonsegmental instrumentation (e.g., Harrington rod technique, pedicle fixation across one interspace, atlantoaxial transarticular screw fixation, sublaminar wiring at C1, facet screw fixation)
22841	Internal spinal fixation by wiring of spinous processes
22842	Posterior segmental instrumentation (e.g., pedicle fixation, dual rods with multiple hooks and sublaminar wires); 3 to 6 vertebral segments
22843	Posterior segmental instrumentation (e.g., pedicle fixation, dual rods with multiple hooks and sublaminar wires); 7 to 12 vertebral segments
22844	Posterior segmental instrumentation (e.g., pedicle fixation, dual rods with multiple hooks and sublaminar wires); 13 or more vertebral segments
22845	Anterior instrumentation; 2 to 3 vertebral segments
22846	Anterior instrumentation; 4 to 7 vertebral segments
22847	Anterior instrumentation; 8 or more vertebral segments
22848	Pelvic fixation (attachment of caudal end of instrumentation to pelvic bony structures) other than sacrum
22849	Reinsertion of spinal fixation device
22851	Application of intervertebral biomechanical device(s) (e.g., synthetic cage[s], methylmethacrylate) to vertebral defect or interspace. Note that this code descriptor has been modified for 2011 to eliminate "threaded bone dowel[s]".
22852	Removal of posterior segmental instrumentation
22855	Removal of anterior instrumentation

22899	Unlisted procedure, spine
32905	Thoracoplasty, Schede type or extrapleural (all stages)

Slipped Capital Femoral Epiphysis Procedure CPT Codes	
27175	Treatment of slipped femoral epiphysis; by traction, without reduction
27176	Treatment of slipped femoral epiphysis; by single or multiple pinning, in situ
27177	Open treatment of slipped femoral epiphysis; single or multiple pinning or bone graft (includes obtaining graft)
27178	Open treatment of slipped femoral epiphysis; closed manipulation with single or multiple pinning
27179	Open treatment of slipped femoral epiphysis; osteoplasty of femoral neck (Heyman type procedure)
27181	Open treatment of slipped femoral epiphysis; osteotomy and internal fixation

Developmental Dysplasia of the Hip CPT Codes	
20680	Removal of implant; deep (e.g. buried, wire, pin, screw, metal band, nail, rod or plate)
29325	Cast one and one-half spica or both legs
27095	Injection procedure for hip arthrography; with anesthesia
27256	Treatment of spontaneous hip dislocation (developmental, including congenital or pathological), by abduction, splint or traction; without anesthesia, without manipulation
27257	Treatment of spontaneous hip dislocation (developmental, including congenital or pathological), by abduction, splint or traction; with manipulation, requiring anesthesia
27258	Open treatment of spontaneous hip dislocation (developmental, including congenital or pathological), replacement of femoral head in acetabulum (including tenotomy, etc.)
27259	Open treatment of spontaneous hip dislocation (developmental, including congenital or pathological), replacement of femoral head in acetabulum (including tenotomy, etc.); with femoral shaft shortening

Appendix B. Literature Review Search Strategy

Literature was identified using PubMed, an archive of biomedical and life science journal literature at the U.S. National Institutes of Health's National Library of Medicine. Search terms were created using a combination of free text and Medical Subject Headings (MeSH) within the PubMed database (Tables 1 and 2). Exclusion criteria restricted the review to articles from English-only peer-reviewed journals. The type of studies allowed in the literature review was restricted to economic studies, clinical studies, literature reviews, and meta-analyses. As a result, individual case series, reviews, letters, and commentaries were excluded. The patient population must have had slipped capital femoral epiphysis, developmental dysplasia of the hip, or scoliosis as an adolescent or young adult. Studies focused on adult populations must have also observed adolescents and young adults at the time of treatment.

The search strategy consisted of three steps: 1) title screening; 2) abstract screening; and 3) full-text paper screening. Two team members independently reviewed the articles. If there were any disagreed about inclusion, a third researcher assisted with the reconciliation process and discussed any discrepancies until a consensus was reached. References were reviewed to capture any relevant articles. Study characteristics, such as authors, publication year, methods, setting, sample size, outcome measures, results, and conclusions were extracted from articles and inputted into a Microsoft Excel spreadsheet. Study quality was evaluated and monitored for any biases or conflicts of interest that could compromise the validity of our review.

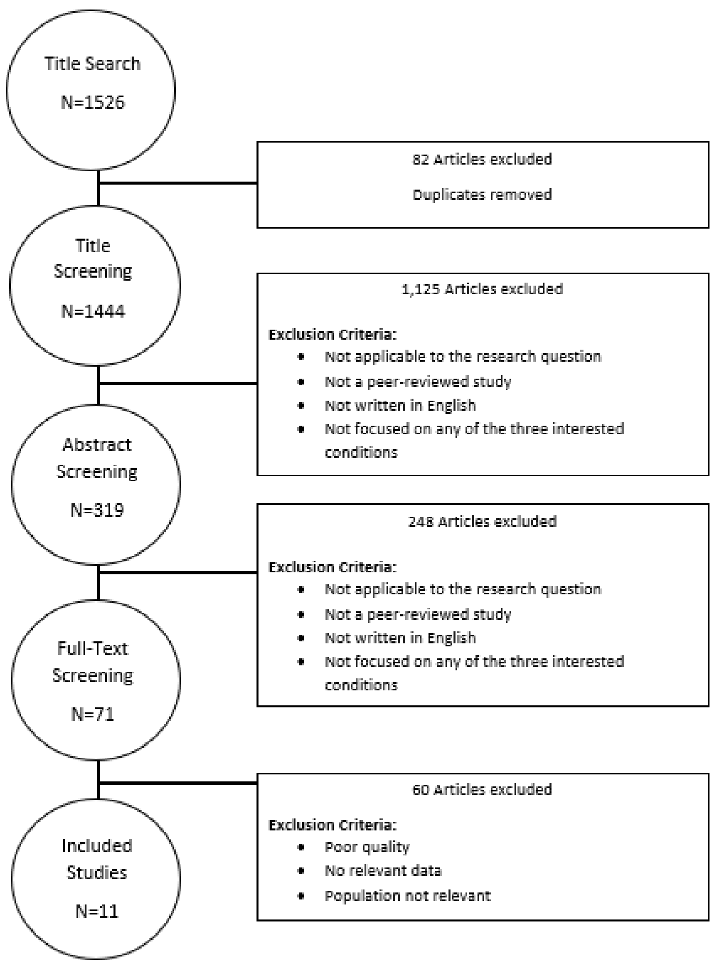
Table 1. MeSH Terms

MeSH Heading
Absenteeism
Acute Pain
Behavior and Behavior Mechanisms
Caregivers
Chronic Pain
Costs and Cost Analysis
Disability Evaluation
Disease Progression
Hip Dislocation, Congenital
Osteoarthritis
Osteotomy
Quality of Life
Rehabilitation
Scoliosis
Sick Leave
Slipped Capital Femoral Epiphyses
Socioeconomic Factors
Unemployment

Table 2. Free Text Terms

Free Text Terms
“Developmental Dislocation of the Hip”
“Developmental Dysplasia of the Hip”
“Hip Osteotomy”
“Pelvic Osteotomy”
“Scoliosis Brace”
“Scoliosis Surgery”
“Scoliosis Treatment”
“Scoliosis”
“Slipped Capital Femoral Epiphysis”
“Slipped Upper Femoral Epiphysis”
“Surgical Dislocation of the Hip”

Appendix C. Literature Review Attrition Chart



Appendix D. Average Annual Physician Visits for Children with Select Musculoskeletal Conditions per 10,000 Adolescents*

	2006-2008		2009-2011		Total (2006-2011)		
	Physician Visits	**Rate per 10,000 Adolescents**	**Physician Visits**	**Rate per 10,000 Adolescents**	**Annual Physician Visits**	**Total Physician Visits**	**Rate per 10,000 Adolescents**
Scoliosis	1,082,923	33	1,841,598	56	487,420	2,924,521	45
DDH	129,713	10	216,591	16	57,717	356,289	13

*There were no recorded cases of slipped capital femoral epiphysis in the National Ambulatory Medical Care Survey database.
Sources: Analysis of 2005-2011 National Ambulatory Medical Care Survey and 2000-2010 & 2010-2011 U.S. Census Data.